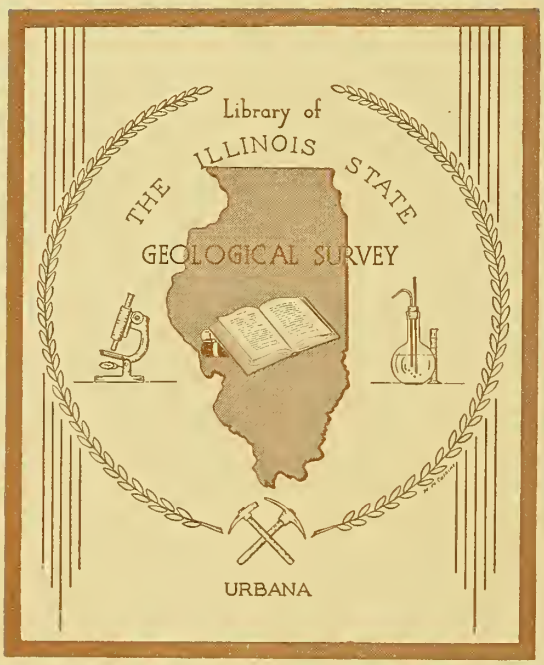


ILLINOIS STATE GEOLOGICAL SURVEY
3 3051 00005 3268

557
I16e
no. 17
Copy 2

ENVIRONMENTAL GEOLOGY NOTES

SEPTEMBER 1967 • NUMBER 17

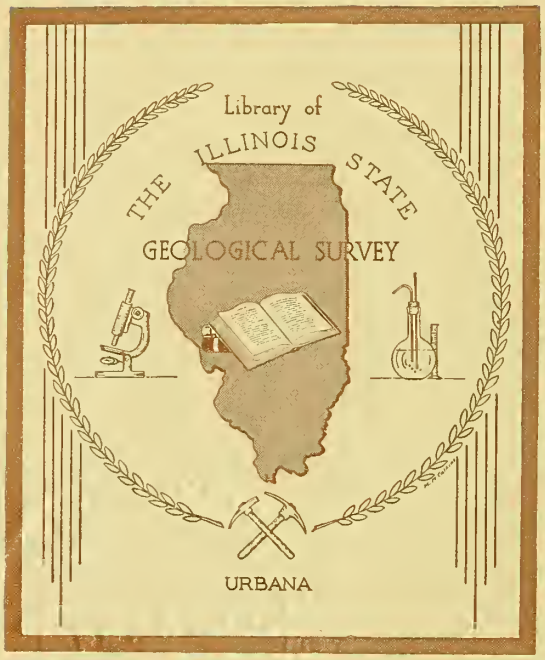
SELECTION OF REFUSE DISPOSAL SITES IN NORTHEASTERN ILLINOIS

GEORGE M. HUGHES

ILLINOIS STATE GEOLOGICAL SURVEY

JOHN C. FRYE, Chief • Urbana

ILLINOIS STATE
GEOLOGICAL SURVEY
LIBRARY


Library of
THE ILLINOIS STATE
GEOLOGICAL SURVEY
URBANA

SELECTION OF REFUSE DISPOSAL SITES IN NORTHEASTERN ILLINOIS

George M. Hughes

Geologic environments in northeastern Illinois were evaluated in terms of results of studies on refuse disposal and ground-water contamination that have been made elsewhere. The geologic environments commonly considered as safe for refuse disposal in this area are those with materials of low permeability and those that are relatively dry. A third type of environment, one which is hydrologically protective, also should be considered for disposal purposes.

INTRODUCTION

Fourteen million cubic yards of refuse were collected in northeastern Illinois in 1960. By 1980, the figure will have risen to 18 million cubic yards a year (Sheaffer, von Boehm, and Hackett, 1963, p. v-vi). Obviously, more disposal sites must be found to take care of this mountain of refuse.

Finding new dumping sites, however, is a complicated matter, for a number of reasons. In several instances, refuse disposal has been proved to have caused contamination of ground water (Ministry Housing and Local Govt. [Gt. Br.], 1961, p. 36-39; Engineering-Science, Inc., 1961, p. 88-90). Three sites investigated in northeastern Illinois showed dissolved solids leached from

ILLINOIS STATE
GEOLOGICAL SURVEY
LIBRARY

refuse had moved out of a disposal area, and in one of the sites the leachate had moved more than 100 yards.

The aquifers of northeastern Illinois present in the glacial drift or shallow bedrock are particularly susceptible to contamination from near-surface refuse disposal (Hackett, 1965, p. 27). In 1961, these aquifers produced 83 million gallons of water per day (Sheaffer and Zeizel, 1966, p. 101), and, as the demand for water increases, the rate of pumping probably will rise. It is therefore essential that the water in these aquifers be protected from contamination.

The Illinois State Geological Survey, at the request of local and state regulatory agencies, prepares geologic reports on operating or prospective landfill disposal sites. These reports are used to help determine whether natural conditions at the sites are adequate to protect the ground-water resource from contamination. A proper evaluation of a disposal site should consider (1) the nature of the contaminants present in the landfill, (2) the conditions under which the contaminants are produced and mobilized, (3) the movement and final disposition of the contaminants, and (4) the effect of the refuse disposal operation on the hydrogeology of the site. The first consideration depends on the composition of the landfill; the others are primarily dependent on the hydrogeologic environment of the landfill site and the method of disposal.

In this particular study, the relation of refuse disposal to ground-water contamination was analyzed. Possible ways of using such information to evaluate disposal sites in northeastern Illinois were determined.

ACKNOWLEDGMENTS

J. E. Hackett, R. A. Landon, and R. E. Williams of the Illinois Geological Survey made suggestions that have been freely incorporated into

Digitized by the Internet Archive
in 2012 with funding from
University of Illinois Urbana-Champaign

http://archive.org/details/selectionofrefus17hugh

this discussion. In addition, R. N. Farvolden, of the Department of Geology, University of Illinois, Wallace C. Koster and John J. Vanderveld, Jr., of the National Disposal Company, Mr. Verdun Randolph, of the State Department of Public Health, the late Mr. John Sexton, of John Sexton Contractors Company, and John R. Sheaffer and Arthur Zeizel, of the Northeastern Illinois Planning Commission have read the manuscript.

INVESTIGATIONS OF POLLUTION FROM SANITARY LANDFILLS

Major investigations of the production and movement of pollutants from landfill sites have been made in California and Great Britain. In California, a series of studies were sponsored by the State Water Pollution Control Board and the U. S. Department of Public Health. The first investigation was of the contaminants produced in ash dumps (U.S.C.L.A. Sanitary Eng. Research Lab., 1952); the second considered leaching from landfills composed of domestic garbage (U.S.C.L.A. Sanitary Eng. Research Lab., 1954, 1955, 1956, 1958, 1960); and the third compiled existing information about the effects of refuse fills on ground water, applied to conditions in California (Engineering-Science, Inc., 1961). Other studies were concerned with gases produced from landfills and factors affecting composition and shrinkage of refuse (Engineering-Science, Inc., 1963-1966; Merz, 1964; Merz and Stone, 1963, 1964).

The British study by the Ministry of Housing and Local Government (1961) dealt with domestic refuse deposited under saturated and unsaturated conditions in Great Britain and with the effects of various types of gravel and sand filtering systems on refuse leachate.

Some of the earliest landfill investigations were carried out in New York (Carpenter and Setter, 1940; Eliassen, 1942b). Existing fills of various ages were sampled to determine the composition of the refuse, leachate, and gases produced. Other studies pertinent to this subject are listed in a

bibliography by Begg (1967). Such investigations have provided a general understanding of the kinds and amounts of products associated with disposal of the usual types of near-surface solid wastes. However, few data are available concerning the movement and abatement or attenuation of these products in various environments. Climatic, hydrologic, and geologic factors strongly influence the production and spread of contaminants from landfill sites, and findings of investigators in other areas should be applied with caution to conditions in northeastern Illinois.

COMPOSITION OF REFUSE

Components of refuse, such as grass clippings, vegetables, and ashes, vary both regionally and seasonally (Engineering-Science, Inc., 1961, p. 34-35; Am. Public Works Assoc. Refuse Disposal Committee, 1961, p. 25-26). Because of these variations and the difficulty of obtaining representative samples, analyses are of limited value. The physical composition of Chicago refuse is described in "Municipal Refuse Disposal" (Am. Public Works Assoc. Refuse Disposal Committee, 1961, p. 45). Descriptions of refuse from other areas are given by Weaver and Keagy (1952, p. 21), Carpenter and Setter (1940, p. 386-388), the Ministry of Housing and Local Government of Great Britain (1961, p. 43, 109), and Engineering-Science,Inc. (1961, p. 33-36). Chemical analyses of refuse are given by Weaver and Keagy (1952, p. 23) and Carpenter and Setter (1940, p. 388).

GASES AND LEACHATES

Formation

Decomposition of refuse is initially aerobic, that is, dependent on the presence of oxygen; however, very soon after burial, anaerobic processes predominate, even in most "dry" fills (Engineering-Science,Inc., 1961, p. 44-45). Water, present either initially in the fill or from percolating rain or ground

water, moves through the fill and leaches the soluble materials in the refuse. Carbon dioxide, produced as the refuse decomposes, dissolves in this water and, in the absence of other reagents, forms a weak acid that facilitates the solution and mobilization of some potential contaminants.

COMPOSITION AND QUANTITIES

Gases produced from decomposing refuse have been the subject of much study in California. In laboratory experiments, refuse packed in drums under controlled conditions was found to produce up to 0.210 cubic feet of gas for each pound of dry refuse (Merz, 1964, p. 1). The major gases found in the drums were carbon dioxide and nitrogen. In a fill at Azusa, California, it was calculated that approximately 330,800 pounds of CO_2 and 14,000 pounds of methane per acre (5640 tons of refuse) per year is being produced (Engineering-Science,Inc., 1965, p. 46). Nitrogen can also be expected but it is not considered a problem. Variations in moisture and temperature cause variations in the amounts of these gases. As the fill stabilizes, the quantities generally decrease.

Table 1 shows the percentages of various components leached from refuse and incinerator ash. Leachate from incinerator ash is included because it has a high amount of dissolved solids. Table 1 has been compiled from various sources, each of which reported different conditions under which leaching took place from different types of refuse.

The amount of water associated with the refuse strongly influences the production of leachates. California studies concluded that, in the area studied, refuse placed "so that no portion of it intercepts the ground water, will not cause impairment of the ground water for either domestic or irrigational use" (U.S.C.L.A. Sanitary Eng. Research Lab., 1954, p. 13). Rainfall

TABLE 1—PERCENTAGES OF MATERIALS LEACHED FROM REFUSE AND ASH
(Based on weight of refuse as received)

Materials leached	Percent leached					
	1*	2*	3*	4*	5*	6*
Permanganate value						
30 min.	0.039					
4 hr.	0.060	0.037				
Chloride	0.105	0.127		0.11	0.087	
Ammoniacal nitrogen	0.055	0.037		0.036		
Biologic oxygen demand	0.515	0.249		1.27		
Organic carbon	0.285	0.163				
Sulfate	0.130	0.084 (as SO_4)		0.011	0.22	0.30
Sulfide	0.011					
Albuminoid nitrogen	0.005					
Alkalinity (as $CaCO_3$)				0.39	0.042	
Calcium				0.08	0.021	2.57
Magnesium				0.015	0.014	0.24
Sodium			0.260	0.075	0.078	0.29
Potassium			0.135	0.09	0.049	0.38
Total iron				0.01		
Inorganic phosphate				0.0007		
Nitrate					0.0025	
Organic nitrogen	0.0075	0.0072		0.016		

*Source of data and conditions of leaching:

1. Ministry of Housing and Local Government [Gt. Brit.], 1961, p. 117. Analyses of leachate from domestic refuse deposited in standing water.

2. Ministry of Housing and Local Government [Gt. Brit.], 1961, p. 75. Analyses of leachate from domestic refuse deposited in unsaturated environment and leached only by natural precipitation.

3. Montgomery and Pomeroy, 1949, p. 4 and 19. Refuse from Long Beach, California. Material leached in laboratory before and after ignition.

4. Engineering-Science, Inc., 1961, p. 39. Estimate based on data reported in "Final Report on the Investigation of Leaching of a Sanitary Landfill" (Sanitary Engineering Research Laboratory, 1954). Domestic refuse in Riverside, California, leached by water in a test bin.

5. Engineering-Science, Inc., 1961, p. 73. Based on data reported in "Investigation of Leaching of Ash Dumps" (Sanitary Engineering Research Laboratory, 1952). Leaching of California incinerator ash in a test bin by water.

6. Engineering-Science, Inc., 1961, p. 73. Based on data reported in "Investigation of Leaching of Ash Dumps" (Sanitary Engineering Research Laboratory, 1952). Leaching of southern California incinerator ash in a test bin by acid.

in the California study area did not penetrate a 7.5-foot thick landfill sufficiently to cause leachate to enter the underlying ground water.

In Britain, rainfall that penetrated one landfill was adequate to produce refuse percolate (Ministry Housing and Local Govt. [Gt. Brit.], 1961, p. 11); however, if the refuse was not deposited in standing water, the total quantity of pollutant produced was somewhat smaller. Out of 25 inches of rainfall per year, 10 inches percolated into the landfill. This fill had been compacted with a vibrating roller to a depth of approximately 5 feet and a density of 6.6 hundredweights per cubic yard. It had a flat surface covered with 18 inches of soil.

MOVEMENT OF GASES AND LEACHATE

Work in California has indicated that of the total amount of carbon dioxide produced in a landfill, 23.5 times as much passes through a 1-foot silt cover into the atmosphere as remains in the ground (Engineering-Science, Inc., 1965, p. 46). Movement into the ground is mainly by molecular diffusion. The California investigation took place in a landfill that was well above the local water table and permitted little or no downward percolation of rainwater. A site with different characteristics probably would have a different rate of diffusion of gases into the ground.

Influence of Ground-Water Flow

Refuse leachate in the subsurface travels in the same direction as ground water, though at a slower rate. In a homogeneous isotropic environment, water moves vertically downward to the top of the zone of saturation, and then in the direction of the potential gradient. The principles governing this movement were discussed by Hubbert (1940), Toth (1962, 1963), and Meyboom (1966), and its effect on the movement of contaminants by Geraghty (1962).

The velocity, direction, and volume of ground-water movement are affected by the topography and the materials the water moves through.

Figures 1A and 1B illustrate the importance of considering the ground-water flow system when selecting disposal sites. In the intervals labeled A, pollutants moving with the ground water could reach the dolomite aquifer, and in intervals labeled B they could reach the sand and gravel aquifer before they are discharged to the surface. In intervals labeled C, pollutants moving with ground water would not reach any aquifer before being discharged, and in the intervals called D, ground-water movement is towards the surface only. Under the ground-water flow conditions shown in figure 1A, there is a much greater area where pollution of an aquifer from surface waste disposal is possible than under the flow conditions shown in figure 1B. The location of the disposal site within the flow system is an important factor. In regional planning, the dimensions of the flow system or flow systems present can provide useful data.

The permeability of the material through which water is moving affects both the velocity and direction of water movement. Unjointed clays and shales are the least permeable of the common sedimentary materials. Sands, gravels, and sandstones are generally most permeable. As water movement in permeable rocks is usually, though not always, through intergranular openings, local flow paths may be predicted with some accuracy. Jointed or fissured rocks, such as dolomites, clays, shales, and lavas, may have high permeability, but, because the water is forced to move through the fissures or cracks,its travel direction and velocity are very difficult to predict, even for short distances.

Calculations of the velocity and direction of water movement based on the assumption that the earth materials are homogeneous and isotropic may

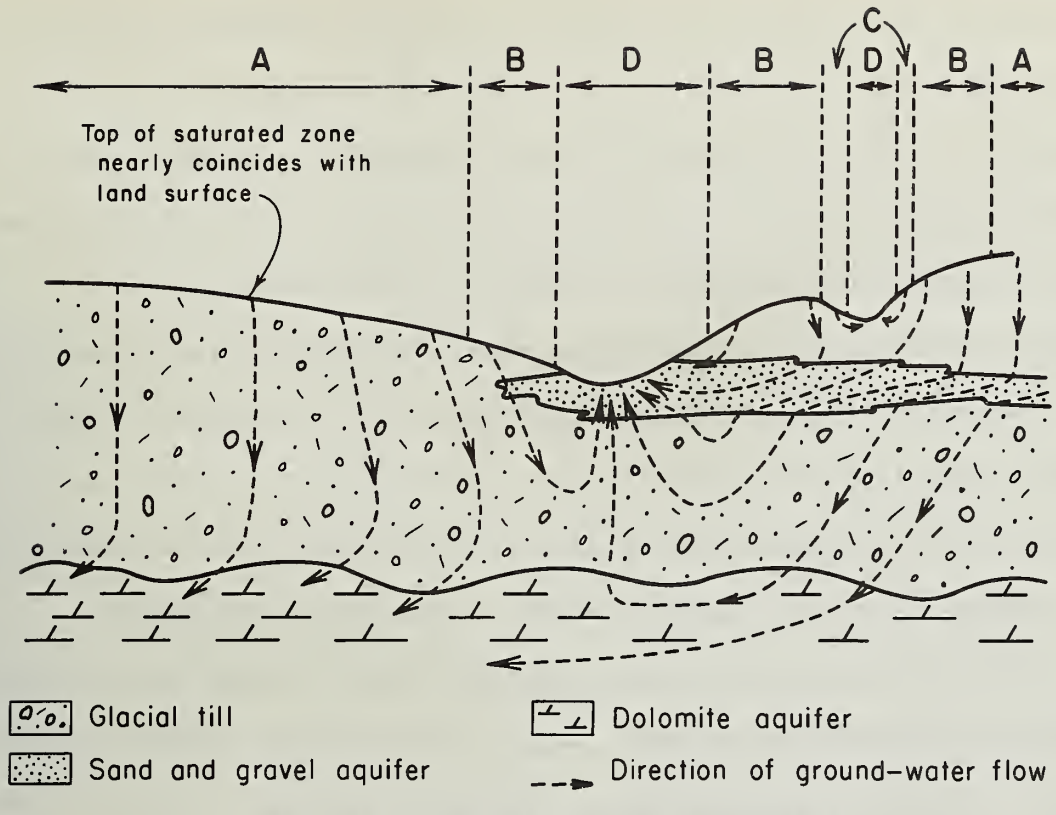


Fig. 1A - Hypothetical Flow System A.

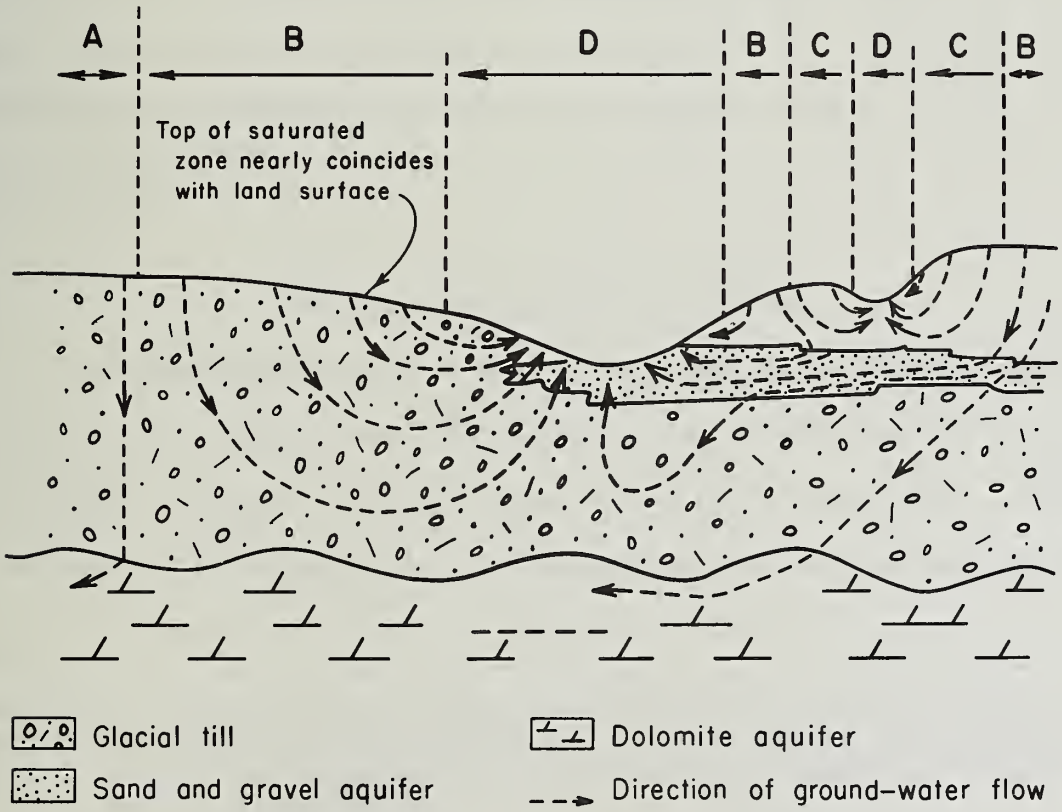


Fig. 1B - Hypothetical Flow System B.

be seriously misleading, as natural deposits seldom have these characteristics. Variations in the kinds of materials may have an effect on the flow system, but it cannot as yet be predicted accurately enough for use in the field unless detailed studies of the hydrologic properties of these materials are made.

Less dilution and dispersion of contaminants takes place in ground water than in surface waters because ground-water flow is almost always laminar, whereas flow of surface water is generally turbulent. For this reason, the total volume in a ground-water reservoir cannot be considered effective for diminishing the concentration of contaminants (McKee and Wolf, 1963, p. 19).

McKee and Wolf (1963, p. 20) also pointed out that the low travel velocities and diffusion rates in ground-water reservoirs can produce serious consequences when contamination occurs. Contamination may not be noticed for years or decades, and consequently no complaints are registered. Even after contamination is discovered, the quality of water is already degraded and the damage cannot be repaired merely by stopping the source of contamination. Purification by leaching and dilution may require a longer time than the contamination did.

NATURAL PURIFICATION OF LEACHATE

Ion exchange* may hold contaminants within the fill or within the earth materials through which they move. Clays are particularly effective in this respect, but sands and silts also will retain contaminants. The amount of exchange a particular type of cation undergoes depends on several factors,

---

*Grim (1953, p. 126) explains ion exchange as follows: "The clay minerals have the property of sorbing certain anions and cations and retaining these in an exchangeable state, i.e., these ions are exchangeable for other anions or cations by treatment with such ions in a water solution . . ."

including (1) the type of clay mineral involved, (2) the cations already on the clay, (3) the other cations in solution and their concentrations, and (4) accompanying anions.

Laboratory experiments to determine how much exchange will take place as a solution is passed through a given material may yield useful results, although extrapolation to field conditions requires care (McHenry et al., in de Laguna, 1955, p. 190). In such experiments most of the soil is in contact with the solution, but under field conditions in which permeability varies because of minor sand bands or fractures this may not be the case.

Considerable work has been done on ion exchange on soils in relation to radioactive wastes disposal (de Laguna, 1955). For more basic understanding of ion exchange on clay minerals, the reader is referred to Grim (1953, 1962).

Self purification, particularly of organic matter, takes place within the fill itself (Ministry Housing and Local Govt. [Gt. Brit.], 1961, p. 11, 26). The degree of purification depends on the length of time the refuse leachate remains in the fill.

The Ministry of Housing studies in England (1961, p. 23) established that by passing refuse leachate through sand and gravel filters "general purification from organic matter can be effected under anaerobic conditions." Purification from chlorides, sulfates, and ammonia was found to be much less complete. Although aerobic purification would be more efficient, it is not likely to be effective in ground waters.

Investigation by McCormick (1966, p. 46) in South Dakota disclosed that the hardness and alkalinity of leachate-contaminated ground water were substantially reduced as the water passed through a small surface pond. Although no use has been made of this method, it may be worth considering in the selection of disposal sites.

STABILIZATION OF LANDFILLS

Stabilization of landfills depends primarily on the rate of decomposition of their organic matter, which Eliassen (1942a, p. 913) found in New York proceeded most rapidly when the refuse had a moisture content of 40 to 80 percent. The most rapid stabilization I could find described in the literature was for a fill in a swamp near New Orleans (Schneider, 1953, p. 84). After three years the materials in this fill were inert enough to be used as cover for subsequent disposal operations. In San Francisco, however (Am. City, 1947, p. 11), a 12-year-old fill showed little evidence of decomposition. Other descriptions of disinterred refuse of various ages have been given by Carpenter and Setter (1940, p. 388), Longwell (1957, p. 423, 424), Montgomery and Pomeroy (1949, p. 14), and Weaver and Keagy (1952, p. 22).

ENGINEERING PROCEDURES TO PROTECT GROUND WATER

Impermeable Liners

To prevent movement of pollutants, the base and/or sides of a disposal area are commonly lined with a 1- or 2-foot layer of compacted clay. One of the few detailed studies of how efficiently a clay liner prevents water movement was made on a 3-foot deep freshwater lagoon at the 1938 Golden Gate International Exposition in San Francisco (Lee, 1941). The liner was 10 inches thick and had been compacted with a 14-ton flat roller. Loss through the liner was initially 1.00 inch per day, but the loss was reduced to 0.10 inch per day after the liner had been treated with sea water.

The results of this study should be applied with caution to refuse disposal problems as the conditions described above differ from those expected of a landfill in three respects. First, the composition of landfill leachate differs from that of sea water, and it is possible that the clay minerals

would react to leachate in a manner that produced an increase rather than a decrease in permeability. Next, the lagoon at San Francisco was used to hold fresh water, which in time leached the clay and necessitated retreatment with sea water. A liner in a refuse pit is constantly in contact with leachate, and treatment of the liner would be impractical. Finally, the liner in San Francisco was not as greatly compacted as liners beneath disposal sites might be.

In Lake County, Illinois, contaminants from a landfill operation lined with uncompacted clay were found to have moved a few feet into the surrounding materials (Hughes and Duel, 1966, p. 7). In South Dakota a bentonite seal used in a waste stabilization pond in extremely sandy soil also was found to leak (Carl and Kalda, 1960, p. 122). The use of clay liners for sealing refuse disposal sites, where minor amounts of leakage may be quite significant, must therefore be more fully evaluated.

Impermeable Covers

It has been suggested that graded, compacted clay covers be used on completed landfills to prevent the downward percolation of rain that might leach the fill materials. This procedure may have some advantages in areas with heavy rainfall; however, such a liner would also restrict movement of landfill gases, principally carbon dioxide, into the atmosphere, diverting it downward and laterally into the surrounding soil. This problem has been considered in California (Engineering-Science, Inc., 1965).

Collection and Disposal of Leachate

Landfill sites could possibly be waterproofed at the base and tiled to divert leachate to a collection point where it can be removed and treated (Ministry of Housing and Local Govt. [Gt. Brit.], 1961, p. 28).

Re-Use of Proved Sites

Removal of nearly stabilized and inert refuse from a site proved safe so that the site could be re-used for disposal of new refuse has been proposed (Ministry of Housing and Local Govt. [Gt. Brit.], p. 28, 1961). The old refuse could then be disposed of at other sites, where, because of its reduced potency, it would have no harmful effects. This procedure would probably not be warranted unless the environment was such that additional safe sites could not be found or easily constructed.

FAVORABLE SITES FOR DISPOSAL

Dry Conditions

A disposal site is usually considered favorable if the refuse will remain dry or unsaturated, thus reducing the production of contaminants and preventing their mobilization.

Two types of sites fall into this class. In the first are sites where disposal takes place below the ground surface but above the zone of saturation. The second type includes sites where refuse is disposed of on the ground surface and, if necessary, covered and graded to prevent the entrance of water.

In arid areas, investigations have shown that leachate from refuse deposited in either of such ways will not pollute the ground water. In humid areas the same would probably hold true, but it becomes difficult to find sites where excavations will not intersect the zone of saturation and even more difficult to place a permanent impermeable cover on the completed fill.

Geologically Favorable Conditions

A disposal site is considered satisfactory if the permeability of the earth materials at the site is low enough to retard movement of contaminants

from the site. In most instances, materials with permeabilities of less than 10^{-2} gal/day/ft^2 are considered as relatively impermeable. In laboratory measurements, clays and tills fall into this class (Todd, 1959, p. 53). At a hydraulic gradient of 1 foot per foot and a specific yield of 5 percent, ground-water velocity through such material would be approximately 0.026 feet per day or nearly 10 feet per year.

Disposal in this type of environment depends on the low permeability of the surrounding earth materials to

a) retard movement of contaminants from the disposal site until their potency has been considerably reduced by bacterial or chemical processes;

b) attenuate contaminants in their passage away from the disposal site by adsorption and filtration; and

c) minimize the rate at which any contaminants could be introduced into a potable water supply.

No comprehensive investigations have been made of disposal sites in materials with low permeability, and the actual extent of spread of contaminants in such environments is unknown.

Hydrologically Favorable Conditions

Under conditions that are hydrologically favorable, movement of contaminants along lines of flow would be such that either they could not reach a useful ground-water or surface-water resource, or their attenuation to acceptable levels would occur before they reached such a water resource.

The major advantage of disposal in such environments is that pollutants need not be retained at a site for an indefinite period and the refuse need not be kept dry until the fill has stabilized. In a hydrologically safe site, the continued presence of contaminants should not be a problem.

Selection of hydrologically safe sites depends on an understanding of the ground-water flow system, which may be difficult to acquire. This is

perhaps the greatest drawback to consideration of this kind of environment for disposal purposes.

Other disadvantages include the necessity of imposing some control over factors that may change the flow system, such as nearby pumping wells or reservoirs. In some cases, the rate of contamination attenuation and the tolerated concentration of contaminants that could be accepted in aquifers or surface waters must be established.

In spite of these disadvantages, hydrologically safe environments show a great deal of promise as sites for waste disposal, and the possibility of their use in northeastern Illinois is discussed in more detail later.

CONDITIONS RELATED TO REFUSE DISPOSAL IN NORTHEASTERN ILLINOIS

Climate

A major factor influencing the production of leachate from landfills is the amount of rainfall that penetrates the refuse. At Chicago Midway Airport the mean annual precipitation is 33.18 inches (U. S. Weather Bur., 1962, p. 2-3). Judging from the studies on leaching previously noted, rainfall in northeastern Illinois could be expected to be adequate to penetrate a landfill unless protective measures were taken.

Geology

The unconsolidated deposits above the bedrock in northeastern Illinois, with the exception of recent stream and bog deposits, were deposited as a result of continental glaciation. The bulk of these materials is glacial till—an unsorted, unstratified deposit of boulders, sand, silt, and clay—and various types of bedded sands, gravels, and silts deposited by streams derived from ice meltwaters.

The majority of the glacial tills in northeastern Illinois are fine textured with low, intergranular permeabilities, probably less than 10^{-2} gal/day/ft^2. There is evidence (Williams, 1966; Meyboom, Everdingen, and Freeze, 1966), however, that jointing is present in these tills, and if joints are present at a disposal site they could allow the passage of contaminants at higher rates than might be anticipated. Localities where tills are more than 30 feet thick are common, and such deposits have been considered as relatively impermeable.

Sand and gravel deposits are relatively permeable, and have been, and probably will continue to be, developed as aquifers in the areas. These deposits are often present at or near the surface in the major valleys, but some are buried in the drift sequence of both upland and lowland areas.

The sands and gravels, though permeable, probably act as a filter to inhibit the movement of bacterial, though not chemical, contaminants at disposal sites.

The upper part of the bedrock of most of northeastern Illinois is composed of jointed dolomites of Silurian age. The dolomite is permeable and is a major source of water. In the rest of northeastern Illinois the bedrock is composed of less permeable, jointed shales and dolomites of the Maquoketa Group, or of sandstones and shales of Pennsylvanian age. These units also are sources of water, though not nearly so important as the drift or Silurian rocks. Jointed rocks are particularly susceptible to contamination, because they contain passages through which contaminants may move very rapidly without appreciable attenuation.

Zone of Saturation

Although it is generally considered good policy to deposit fill materials above the zone of saturation, in northeastern Illinois this is seldom

possible unless the fill is deposited on the ground surface. Observations made by the Illinois Geological Survey during a surficial mapping program in DuPage County and by Williams (1966) indicate the following general relations existing in northeastern Illinois.

1) In fine-textured earth materials in both upland and lowland areas, the zone of saturation is generally within 10 feet of land surface.

2) In coarse-textured earth materials in lowland areas, the zone of saturation is generally within 5 feet of land surface.

3) In coarse-textured earth materials on uplands and on valley walls, the depth to saturation varies from place to place and may be more than 10 feet below land surface. Such conditions are not common in northeastern Illinois, except in the Chain O' Lakes area, parts of Kane and McHenry Counties, and in the valley walls of the DesPlaines and Fox Rivers.

In predominantly fine-textured materials, such as the glacial till, the actual appearnce of ground water in excavations below the top of the zone of saturation usually depends on the presence of minor permeable zones, such as thin sand partings or joints. Evaporation alone may be adequate to keep such excavations dry. However, after the excavation is filled, and evaporation reduced, the ground water will saturate the fill materials. Piezometers give the most reliable data on saturation levels at proposed sites; water levels measured in nearby wells depend to a large extent on well depth and are not reliable for determining the depth at which saturated conditions occur.

Seasonal and annual variations in the level of the zone of saturation should be considered when evaluating proposed sites. It is generally highest in the spring and fall and lowest in the summer. Major changes in the level of saturation also result from individual rainstorms (Williams, 1966).

Cation Exchange Capacity of Soils

Data available on the cation exchange* capacity of northeastern Illinois soils (Wascher et al., 1960, App. C) indicate that the base saturation in the C horizon† is 100 percent (all exchange positions filled), the major exchangeable cations being calcium and magnesium. Under these conditions, although sorption of contaminants will still take place, it is likely to be less than if the base saturation were below 100 percent and the exchangeable cation was, for example, sodium, which is less tightly bound. Because the base saturation is 100 percent, the replacement of calcium and magnesium by pollutants in the leachate will result in their release into the ground water and increase its hardness.

Stabilization Time

Not all of the factors controlling the rate of decomposition of refuse are known, but oxygen and moisture are undoubtedly important. Their presence or absence are, in turn, affected by the amount of compaction of the refuse, the type of refuse, the environment in which the refuse was emplaced, the cover over the refuse, and the depth of the fill. A reliable estimate of the time required for refuse to stabilize in the Chicago area is as yet not possible.

FAVORABLE CONDITIONS FOR REFUSE DISPOSAL IN NORTHEASTERN ILLINOIS

Dry Conditions

Environments in which dry conditions occur below the ground surface are relatively rare in northeastern Illinois. However, sites for surface

---

*Base or cation exchange is the ability of a clay mineral to adsorb bases (cations) and exchange them for other cations introduced into the clay-water system.

†In most cases the C horizon will be representative of the materials in which the fill is emplaced.

disposal are available that might be suitable if the refuse were covered to prevent the entrance of water.

Rainfall in northeastern Illinois is adequate to leach unprotected landfills and, therefore, a suitable impermeable cover is necessary until the fill has stabilized. Precipitation entering a surface fill could develop a ground-water mound within the fill area, and movement of contaminants would be accelerated. Minor seeps from the sides of two fills in northeastern Illinois show this does occur.

Geologically Favorable Conditions

Much of northeastern Illinois is underlain by thick glacial tills that have low permeability, and sites in this type of environment would be relatively easy to locate. As mentioned previously, however, the actual spread of contaminants in such environments has not been established and should be investigated before such sites are used.

Hydrologically Favorable Conditions

Although sites may be available at which the hydrologic conditions are such that movement of contaminants would not be hazardous, such environments are seldom considered for disposal purposes. Their advantages and disadvantages are very difficult to evaluate.

While the general principles governing ground-water movement are fairly well understood and the direction of movement of near-surface ground water is relatively easy to determine with piezometers, it is not yet possible to determine the regional flow system without intensive investigation. For example, in northeastern Illinois streams are, by and large, zones of ground-water discharge; that is, ground-water movement is upward into the stream, rather than downward from the stream into the ground. The width of these

discharge zones and how far the zone of upward water movement extends beneath the streams have not been determined.

Recharge (downward movement of water into the ground) occurs in the uplands, but how far the zone of downward water movement extends under any given upland is still not recognized. It has been noted in northeastern Illinois (Williams, 1966) and elsewhere (Meyboom, 1966) that a single locality, such as a marsh, may at various times act as either a recharge or discharge zone. The Illinois Geological Survey and the University of Illinois, with the cooperation of the State Department of Public Health, are conducting an investigation, funded in part by the U. S. Public Health Service, of the hydrogeologic environments of various solid waste disposal sites in northeastern Illinois, and of the problems associated with ground-water contamination and solid waste disposal in the area.

Disposal of refuse in upland areas would provide a long travel path, and therefore, increased contact for attenuation of contaminants (fig. 1). This procedure has been recommended in Nevada, where water use is principally in the valleys and where long travel paths exist from recharge areas in the mountains to discharge in the valleys (Maxey and Farvolden, 1965). In northeastern Illinois, however, aquifers are commonly present within a few tens of feet of the ground surface under both valleys and uplands, and the distances between recharge and discharge areas may be relatively short. Before upland refuse sites were recommended it would be necessary to demonstrate that pollutants introduced in upland recharge areas would not move downward into these aquifers before being attenuated to an acceptable level.

In lowland discharge areas—such as most river valleys, lakes, and marshes—the direction of ground-water movement is generally upward, and under natural conditions contamination of aquifers beneath the disposal site should

not result directly from near-surface refuse disposal even in permeable materials. Contaminants released in discharge areas would probably have access to surface waters; however, a certain amount of purification, particularly of organics, would occur before these pollutants reached the surface waters. The amount of purification would, in part, depend on the distance the water moved through earth materials, which would in turn depend largely on the magnitude of the lateral component of movement at the disposal site. Dilution, particularly by streams, would further reduce contaminant concentration at the surface.

Discharge areas are commonly on low, often wet areas that are difficult to work in. In northeastern Illinois, valley discharge areas are subject to frequent flooding, and it is possible that the disposal operation itself would constrict the valley and cause a flooding problem.

Many sites in northeastern Illinois, including some in permeable materials, might be considered for disposal in discharge zones; however, as this could result in the movement of some dissolved solids into surface waters, establishment of criteria or limits governing the quality of water which could be discharged into streams, lakes, or marshes under various conditions would be necessary.

CONCLUSIONS

Ground water from the drift and shallow bedrock aquifers in northeastern Illinois is widely used at the present time, and likely to become more important in the future. The major shallow aquifer, the Silurian dolomite, is a fractured rock and particularly susceptible to pollution. In view of the difficulties involved in preventing the production and spread of leachates, waste disposal sites should be selected with particular care.

Rainfall alone in northeastern Illinois is probably adequate to saturate a landfill and produce leachates.

There are probably few areas in northeastern Illinois where refuse can be disposed of in excavations above the zone of saturation; therefore, in many instances the consequences of disposal in saturated environments must be considered.

Many areas in northeastern Illinois are underlain by thick glacial tills with low permeability. Such areas may be favorable for disposal purposes.

Consideration should be given to selecting hydrologically favorable sites in discharge areas where "dry" and geologically favorable conditions are not the only safeguards against leachate movement.

REFERENCES

American City, 1947, What happens inside a sanitary fill?: Am. City, v. 62, no. 5, p. 11.

American Public Works Association Refuse Disposal Committee, 1961, Municipal refuse disposal: Am. Public Works Assoc. (A.P.W.A.) Research Found. Proj. 104, Public Adm. Service, Chicago, 506 p.

Begg, B. A., 1967, Sanitary landfill—A bibliography: Drexel Inst. Technology, Civil Engineering Dept., Philadelphia, Pa., 20 p.

Carl, C. E., and Kalda, D. C., 1960, Waste stabilization ponds in South Dakota, in West stabilization lagoons: U. S. Public Health Service Pub. 872, 1961, p. 18-123.

Carpenter, L. V., and Setter, L. R., 1940, Some notes on sanitary landfills: Am. Jour. Public Health, v. 30, no. 4, p. 385-393.

Eliassen, Rolf, 1942a, War conditions favor landfill refuse disposal: Eng. News Record, v. 128, no. 22, p. 912-914.

Eliassen, Rolf, 1942b, Decomposition of landfills: Am. Jour. Public Health, v. 32, no. 9, p. 1029-1037.

Engineering-Science, Inc., 1961, Effects of refuse dumps on ground-water quality: California Resources Agency, California Water Pollution Control Board Pub. 24, 107 p., Sacramento, Calif.

Engineering-Science, Inc., 1963-1966, In situ investigation of movements of gases produced from decomposing refuse: Ann. Repts. 1-4, Prog. Repts. 1-12, California Water Quality Control Board, Eng.-Sci., Inc., Arcadia, Calif.

Geraghty, J. J., 1962, Movements of contaminants through geologic formations: Water Well Jour., v. XVI, no. 3, p. 12-13, 44-48.

Grim, R. E., 1953, Clay mineralogy: McGraw-Hill Book Co., Inc., New York, 384 p.

Grim, R. E., 1962, Applied clay mineralogy: McGraw-Hill Book Co., Inc., New York, 422 p.

Hackett, J. E., 1965, Ground-water contamination in an urban environment: Ground Water, v. 3, no. 3, p. 27-30.

Hubbert, M. King, 1940, The theory of ground-water motion: Jour. Geology, v. 148, no. 8, pt. 1, p. 785-944.

Hughes, G. M., and Duel, Ward, 1966, Report on the investigation of a landfill in Lake County: Illinois Geol. Survey Open File Rept., 8 p.

Laguna, W. de, 1955, Sanitary engineering aspects of the atomic energy industry—A seminar sponsored by the Atomic Energy Commission and the Public Health Service, Robert Taft Engineering Center, Cincinnati, December 1954: U. S. Atomic Energy Comm. Rept. T 1D-7517,pt. 1a, Office Tech. Services, Dept. Commerce, Washington, D. C.

Lee, C. H., 1941, Sealing the lagoon lining at Treasure Island with salt: Am. Soc. Civil Engineers Trans.,v. 106, p. 577-607.

Longwell, John, 1957, The water pollution aspect of refuse disposal: Inst. Civil Engineers Proc., v. 8, p. 420-424.

Maxey, G. B., and Farvolden, R. N., 1965, Hydrogeologic factors in problems of contamination in arid lands: Ground Water, v. 3, no. 4, p. 29-32.

McCormick, J. H., 1966, Chemical variation of ground-water quality in the vicinity of a refuse landfill: South Dakota State Univ., unpublished M.S. thesis, Brookings, S. D., p. 59.

McKee, J. E., and Wolf, H. W., 1963, Water quality criteria [2nd ed.]: California Resources Agency, California Water Quality Control Board Pub. 3-a, 548 p.

Merz, R. C., 1964, Investigation to determine the quantity and quality of gases produced during refuse decomposition: Final Rept. to California Resources Agency, California Water Quality Control Board, Dec. 1, 1961 - June 30, 1964, Standard Service Agreement nos. 12-13, Univ. Southern California, Eng. Center Rept. 89-10, Los Angeles, 35 p.

Merz, R. C., and Stone, Ralph, 1963, Factors controlling utilization of sanitary landfill site: Final Rept., Dept. Health, Education, and Welfare, Natl. Inst. Health, U. S. Public Health Service Proj. EF-00160-03, Univ. Southern California, Dept. Civil Eng., 125 p.

Merz, R. C., and Stone, Ralph, 1964, Factors controlling utilization of sanitary landfill site: First Prog. Rept., Dept. Health, Education and Welfare, Natl. Inst. Health, Proj. EF-00160-04, Univ. Southern California, Los Angeles, 32 p.

Meyboom, Peter, 1966, Unsteady ground-water flow near a willow ring in hummocky moraine: Jour. Hydrology, v. 4, p. 38-62.

Meyboom, Peter, Everdingen, R. O. Van, and Freeze, R. A., 1966: Patterns of ground-water flow in seven discharge areas on Saskatchewan and Manitoba: Canada Geol. Survey Bull. 147, 57 p.

Ministry of Housing and Local Government, 1961, Pollution of water by tipped refuse: Rept. Tech. Committee on Experimental Disposal of House Refuse in Wet and Dry Pits, Her Majesty's Stationery Office, London, 141 p.

Montgomery, and Pomeroy, R. D., 1949, Report of investigation for City of Long Beach regarding probable effects of proposed cut-and-cover trash disposal: Montgomery and Pomeroy, Engineers-Chemists, Pasadena, Calif., 25 p.

Schneider, Carl, 1953, Sanitary fill re-used safely: Am. City, v. 68, no. 10, p. 83-84.

Sheaffer, J. R., von Boehm, Berndt, and Hackett, J. E., 1963, Refuse disposal needs and practices in northeastern Illinois: Northeastern Illinois Metropolitan Area Plan. Comm. Tech. Rept. 3, 72 p.

Sheaffer, J. R., and Zeizel, A. J., 1966, The water resource in northeastern Illinois—Planning its use: Tech. Rept. 4, Northeastern Illinois Plan. Comm., Chicago, 182 p.

Todd, D. K., 1959, Ground-water hydrology: John Wiley and Sons, Inc., New York, 336 p.

Toth, J., 1962, A theory of ground-water motion in small drainage basins in central Alberta: Jour. Geophys. Research, v. 67, no. 11, p. 4375-4387.

Toth, J., 1963, A theoretical analysis of ground-water flow in small drainage basins: Jour. Geophys. Research, v. 68, no. 16, p. 4795-4812.

University Southern California, Los Angeles, Sanitary Engineering Research Laboratory, 1952, Investigation of leaching of ash dumps: California Water Pollution Control Board Pub. 2, 100 p., Sacramento, Calif.

University Southern California, Los Angeles, Sanitary Engineering Research Laboratory, 1954, Final report on the investigation of leaching of a sanitary landfill: California Water Pollution Control Board Pub. 10, 92 p., Sacramento, Calif.

University Southern California, Los Angeles, Sanitary Engineering Research Laboratory, 1955, 1956, 1958, 1960, Reports on continuation of an investigation of leaching of rubbish dumps: Univ. Southern California, Los Angeles, Eng. Center Rept. 38-3, 1955; 46-3, 1956; 64-3, 1958; 72-3, 1960.

United States Weather Bureau, 1962, Climatic guide for Chicago, Illinois, Area, in Climatography of the United States, no. 40-11: U. S. Govt. Printing Office, Washington, D. C., 48 p.

Wascher, H. L., Alexander, J. D., Ray, B. W., Beavers, A. H., and Odell, R. T., 1960, Characteristics of soils associated with glacial tills in northeastern Illinois: Univ. Illinois Agr. Expt. Sta. Bull. 665, 155 p.

Weaver, Leo, and Keagy, D. M., 1952, The sanitary landfill method of refuse disposal in northern states: U. S. Dept. Health, Education and Welfare, Public Health Service Pub. 226, 31 p.

Williams, R. E., 1966, Shallow hydrogeology of glacial drifts in northeastern Illinois: Univ. Illinois Ph.D. thesis, Urbana, Ill., 179 p.

ILLINOIS STATE
GEOLOGICAL SURVEY
LIBRARY

ENVIRONMENTAL GEOLOGY NOTES SERIES

1. Controlled Drilling Program in Northeastern Illinois: J. E. Hackett and G. M. Hughes. April 1965.

2. Data from Controlled Drilling Program in DuPage County, Illinois: Jean I. Larsen and C. R. Lund. May 1965.

*3. Activities in Environmental Geology in Northeastern Illinois: Jean I. Larsen and J. E. Hackett. June 1965.

4. Geological and Geophysical Investigations for a Ground-Water Supply at Macomb, Illinois: Keros Cartwright and D. A. Stephenson. July 1965.

5. Problems in Providing Minerals for an Expanding Population: H. E. Risser. July 1965.

6. Data from Controlled Drilling Program in Kane, Kendall, and DeKalb Counties, Illinois: C. R. Lund. October 1965.

7. Data from Controlled Drilling Program in McHenry County, Illinois: C. R. Lund. November 1965.

8. An Application of Geologic Information to Land Use in the Chicago Metropolitan Region: J. E. Hackett. January 1966.

9. Data from Controlled Drilling Program in Lake County and the Northern Part of Cook County, Illinois: C. R. Lund. March 1966.

10. Data from Controlled Drilling Program in Will and Southern Cook Counties, Illinois: C. R. Lund. May 1966.

11. Ground-Water Supplies Along the Interstate Highway System in Illinois: Keros Cartwright. June 1966.

12. Effects of a Soap, a Detergent, and a Water Softener on the Plasticity of Earth Materials: W. A. White and Shirley M. Bremser. August 1966.

13. Geologic Factors in Dam and Reservoir Planning: W. C. Smith. December 1966.

14. Geologic Studies as an Aid to Ground-Water Management: R. A. Landon. May 1967.

15. Hydrogeology at Shelbyville, Illinois—A Basis for Water Resources Planning: Keros Cartwright and Paul Kraatz. June 1967.

16. Urban Expansion—An Opportunity and a Challenge to Industrial Mineral Producers: H. E. Risser and R. L. Major. September 1967.

---

*Out of print.